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Joint inversion of multiple mode Rayleigh wave dispersion curves and H/V spectral ratios measured from ambient noise: application to the Basque-Cantabrian Basin (N of Spain)

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Many ambient noise tomography applications are based on measuring surface wave group velocities from time-domain cross-correlations. This approach has several downsides, among them being: (A) reliable group velocity measurements require at least an inter-station distance of 3 wavelengths, (B) usually, only the fundamental mode of Rayleigh wave propagation is considered, disregarding the possible contribution to the observed group/phase velocity of higher modes, and (C) surface wave dispersion measurements only offer weak constraints for the very shallow and the very deep shear-wave velocity structure at the periods used in most regional studies.

To overcome these limitations, we propose an inversion scheme based on Aki's spectral formulation. First, we measured Rayleigh wave phase velocities by fitting Bessel functions to the observed cross-correlation spectra, and used these measurements in a tomographic inversion to produce a set of phase velocity maps. Then, we defined a grid of regularly spaced nodes on the phase velocity maps, and used the dispersion information on a non-linear inversion to obtain a 1D shear-wave velocity profile at each node. Our inversion scheme considers the influence of higher modes in the observed phase velocities. The same noise recordings used for measuring surface wave dispersion can be used to determine the H/V spectral ratios at the receivers. The fundamental frequency and the shape of the peaks in the H/V ratios can be related to the thickness of the sediment layers and the impedance contrasts between the sediments and the basement, thus providing additional constraints for the deep shear-wave velocity structure in the vicinity of the receivers. Therefore, for the nodes closer to the receivers, we performed a joint inversion of the Rayleigh wave phase velocities and the H/V spectral ratios.

We applied this methodology to the data provided by the SISCAN-MISTERIOS network, a regularly-spaced grid of 40 broad-band stations with inter-station distances ranging from 27 to 440 km, deployed in the Basque-Cantabrian basin (N Spain) during the period 2014-2018. The Basque-Cantabrian basin (N Spain) is one of the major Mesozoic extensional basins developed during the opening of the Bay of Biscay. In Cenozoic times, the Alpine collision between the European plate and Iberian sub-plate caused the inversion of the normal faults, the reactivation of older (Variscan) thrusts and the creation of new structures. As a consequence, both the depth to the Paleozoic basement and the velocity structure vary greatly across the area, providing a challenging scenario to test the proposed methodology. In spite of some difficulties (i.e. weak impedance contrasts between the Mesozoic sediments and the Paleozoic basement in parts of the basin, problems to retrieve accurate spectral ratios for some stations at the considered frequencies, etc), the application of the methodology described above provided good results in areas where the structure was known in detail, and allowed us to achieve a better constrained image of the 3D shear-wave velocity structure across the whole basin.